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Knowledge Structures for Visualising Advanced Research and Trends

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Abstract

Due to the enormous amount of research publications are available, perceiving the growth of scientific knowledge even in one's own specialise field is a challenge task. It would be helpful if we could provide scientists with knowledge visualisation tools to discover the existence of a scientific paradigm and movements of such paradigms. This chapter introduces the state of the art of visualising knowledge structures. The aim of visualising knowledge structures is to capture intellectual structures of a particular knowledge domain. Approaches to the visualisation of knowledge structures with emphasis on the role of citation-based methods are described. The principal components of factor analysis and Pathfinder network are utilized to reveal new and signification developments of intellectual structure in ubiquitous computing research area. Literature published in the online citation data bases CiteSeer and Web of Science (WoS) are exploited to drive the main research themes and their inter-relationships in ubiquitous computing. The benefit of the results obtained could be for someone new to a specific domain in research study, ubiquitous computing in this case. The outcome uncovers popular topics and important research in the particular domain. Potential developments can be re-used and utilized in other disciplines and share across different research domains.

1. Introduction

Computing technology is a paradigm shift where technology becomes virtually invisible in our lives and is a rapidly advancing and expanding research and development field in this decade. Due to the enormous amount of available scientific research publications, keeping up the growth of scientific knowledge even in one's own specialise field is a challenge task. It would be helpful if we could provide scientists with knowledge visualisation tools to detect the existence of a scientific paradigm and movements of such paradigms. The main scientific research themes are also very difficult to analyze and grasp by using the traditional methodologies. For example, visualising intrinsic structures among documents in scientific literatures could only capture some aspects of scientific knowledge.

This chapter introduces the state of the art of visualising knowledge structures. The aim of visualising knowledge structures is to capture and reveal insightful patterns of intellectual structures shared by scientists in a subject field. This chapter describes approaches to the visualisation of knowledge structure with emphasis on the role of citation-based methods. Instead of depending upon occurrence patterns of content-bearing words, we aim to capture the intellectual structures of a particular knowledge domain.

We focus on the study of ubiquitous computing, also called pervasive computing. Numerous journals and conferences are now dedicated to the study of ubiquitous computing and related topics. Ubiquitous computing was first described by Weiser (1991). Since then, a rich amount of related literatures are published. It would be useful if the content of those publications could be summarised and presented in an easy way to capture structures and facilitate the understanding of the research themes and trend in ubiquitous computing.

The goal of the chapter is to show the scope and main themes of ubiquitous computing research. We begin by examining the survey studies of visualising knowledge structures. Next, the data collection method and intellectual structure techniques, factor analysis and Pathfinder Network, are introduced. The results of the analysis are presented and discussed.

2. Visualising Knowledge Structures

Information visualisation techniques have become a rapid growth research area since the last decade (Card et al 1999; Chen 1999). In information retrieval, the vector-space model (Salton 1991) is an originally and popularly exploited framework for indexing documents based on term frequencies. A focal part of modern statistical probability modelling is Bayesian theorem (Neal 1996), which focuses on the probabilistic relationship between multiple variables and determining the impact of one variable on another. Shannon's information theory (Shannon 1948) describes information could be treated as a quantifiable value in communications. Self-organised feature maps are essentially classification processes through a neural network. (Lin, Soergel and Marchionini 1991) is the first to use self-organised maps to visual information retrieval. WEBSOM organizes textual documents for exploration and search based on self-organised map (Lagus et al 1996).

Visualising knowledge structure is an art of making maps, which shares some intrinsic characteristics with cartography (Chen 2002). Number of useful knowledge visualisation techniques has been applied to detect and extract significant elements from unstructured text. The basis for the visualisation of knowledge structures is formed by the interrelationships between these elements. Citation indexing has been widely applied since 1950s. One of the fundamental objectives of science mapping is to identify the trend associated with a field of study. The map created through citation analysis provides a series of historical data, which cover the literature year by year (Garfield 1975). These maps show intrinsic semantic connections among disciplines of domains. The author co-citation analysis (ACA) was introduced to discover how scientists in a particular subject field are intellectually interrelated as perceived by authors in their scientific publications (White and Griffith 1981). An intellectual structure of prominent authors in the field provides a respectable source for knowledge visualisation.

Knowledge Domain Visualisation (KDV) depicts the structure and evolution of scientific fields (Borner, Chen and Boyak 2002). Some recent works in knowledge discovery and data mining systems compose analysis of engineering domain (Mothe and Dousset 2004; Mothe et al 2006).

2.1 Factor Analysis

Factor analysis is one of the commonly used methods in author co-citation analysis. It has been used to identify the intrinsic dimensionality of given co-citation data in a subject domain. (White and McCain 1995) demonstrates the author co-citation analysis of the information science field that some authors indeed belong to several specialties simultaneously. However, if datasets is big, then the size of the corresponding author co-citation matrix could be large and the analysis becomes computationally complicate and expensive.

White and McCain introduces the raw co-citation should be transformed into Pearson's correlation coefficients using the factor analysis (White and McCain 1995). The correlation coefficients measure the nearness between authors' co-citation profiles. Principal component analysis (PCA) is a suggested alternative to extract factors. The default criterion, Eigen values greater than 1, is normally chosen to decide the number of factors extracted. Missing data should also be replaced by mean co-citation counts for corresponding authors. Pearson's correlation coefficient can be used as a measure of similarity between pairs of authors.

2.2 Pathfinder Network Scaling

Pathfinder network scaling is originally developed by cognitive psychologists for structuring modelling (Schcaneveldt, Durso and Dearholt 1989). Pathfinder network scaling relies on the triangle inequality condition to select the most salient relations from proximity data. The Pathfinder network (PFNET), the results of Pathfinder network scaling, consists of all the vertices from the original graph. The number of edges in a Pathfinder network is driven by the basic structure of semantics. The topology of a PFNET is decided by two parameters q and r. The corresponding network is denoted as PFNET (q, r). The q-parameter controls the scope that the triangular inequality condition should be set. The r-parameter is used to computing the distance of a path. The weight of a path with k links is determined by weights $w1$, $w2$, …, wk of each individual link as follows.

$$W\left(P\right) = \left[\sum_{i=1}^{k} w_i^{\ r}\right]^{\frac{1}{r}}$$

3. Intellectual Structure of Ubiquitous Computing

Numerous amounts of scientific papers publish every year and the accumulated literatures over the years are voluminous. We utilized the methods that have been developed in visualizing information structure to comprehend the entire body of scientific knowledge. The aim is to discover the development in ubiquitous computing.

3.1 Proposed Process

Figure 1 shows a proposed process to construct a full citation graph from the data drawn from online citation databases, WOS and CiteSeer. The proposed procedure leverages the citation index by using key phrases "ubiquitous computing" to query the index and retrieve all matching documents from the database. The documents retrieved by the query are then used as the initial seed set to retrieve papers that are citing or cited by literatures in the initial seed set (Lee and Chen 2007; Chen and Lee 2006; Pozi 2002). The co-citation matrix is derived from the co-citation relationships between papers. A co-citation relationship existed between two papers when a third paper cites them both, i.e., both papers are listed in the reference portion of the third paper. The full citation graph is built by linking all articles retrieved, which includes more documents than the other schemes reviewed earlier.
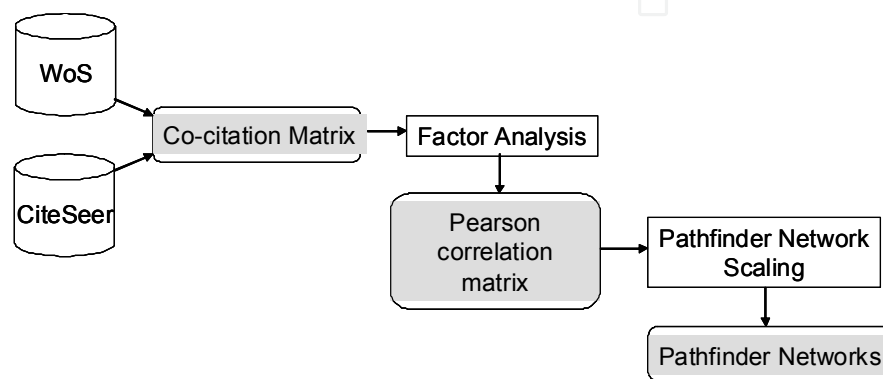

Fig. 1. The Proposed Process

The main usage of the factor analysis is to reduce the number of variables and to detect structure in the relationships between variables. Factor analysis combines correlated variables (papers) into one component (research theme). The co-citation matrix is the input of factor analysis. The co-citation graph is represented by a matrix to compute the correlation matrix of Pearson's correlation coefficients. The Pearson correlation matrix, which is resulted from the factor analysis, is the input of the Pathfinder network scaling. All nodes in a graph are connected by weighted links. The weights are represented by the value of correlation coefficients for each pair of documents.

The citation data are driven from two online citation databases, Citeseer and IS Web of Science (WoS). CiteSeer is an open access free database, which is a scientific literature digital library. Citseer's search engine focuses primarily on the literature in computer and information science. ISI Web of Knowledge database is created by Thomson Reuters in 1997 and integrated access to high quality, multidisciplinary research literature. Web of Science (WoS) is part of ISI Web of Knowledge. WoS covers SCI, SSCI and A&HCI citation databases.

Citation data are collected by querying both databases with the key phrases "ubiquitous computing" and retrieving the initial key papers' information. The key papers are then used as the initial seed set to retrieve papers that are citing or are cited by literatures in the initial seed set (Chen and Xie 2005). A full citation graph is generated by linking all articles retrieved. The depth of the expanded search is restricted to three layers to maintain the most relevant literatures.

3.2 Main Components derived from Factor Analysis

Factor analysis is applied as a data reduction and structure detection method. The co-citation matrixes generated from CiteSeet and WoS are derived from the citation graphs and fed to factor analysis. The unit of analysis is based on documents rather than author due to a researcher's specialty may evolve over time (Chen and Lee 2006; Lee and Chen 2008).

49 components with Eigenvalue over one were identified from the CiteSeer citation data. These factors collectively explained approximately 84.2% total variances. Papers with a loading over 0.6 to a component are collected and studies to determine the content of the component. A proper descriptive name for each component is decided, which represent the research trends in the ubiquitous computing field. Based on CiteSeer citation data, top 10 components and the variances of the components explained are listed in Table 1. Component 9 does not include any papers with loading larger than 0.6 and therefore, is not listed in the table. The content of these nine factors are described in the context of ubiquitous computing.

Factor	Component Name	Variance Explained	Description
1	Routing protocols for mobile and ad hoc networks	7.206	An ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any existing network infrastructure or centralized administration.
2	Location and data management in mobile wireless environment	6.733	Location and data management in a mobile wireless environment is different from the transitional fixed wire environment. Location and data management is required when all the communications over a mobile wireless environment with a sufficient and steady bandwidth.
3	Location and context aware computing	5.702	Location and context aware computing will free the user from the traditional constraints of the desktop. Context refers to the physical and social situation in which computational devices are embedded. Contextual information can be used to provide services that are appropriate to the situational events.
4	Broadcast based data management for asymmetric communication environments	5.023	Broadcasted data has been proposed as a means to efficiently deliver data to clients in asymmetric environments, where the available bandwidth from the server to the clients exceeds the bandwidth in the opposite direction. In the presence of such asymmetry, applications must rely on the broadcast data channel to receive the up-to-date information.
5	Integrating with computer	4.310	Interacting with computer augmented artifacts and environments may greatly

	augmented artifacts and environment		enhance a user's experience. Computer augmented physical objectives or devices may facilitate more effectively computational mediation.
6	Transmission control protocol (TCP) over mobile internetworks	4.120	The study of TCP over mobile internetworks addresses the performance issue of reliable data communication in mobile computing environments. Two changed assumptions need to be addressed in the mobile computing: (1) the end points of the communication link are fixed and (2) the underlying network has high and reliable bandwidth with low latency.
7	Application design for mobile computing	3.524	This factor addresses the disparity of mobile devices in resources, network characteristics, display size, and method of input from application level. Application design strategies may reduce the demands placed on the wireless network.
8	Disconnected operations	3.023	Disconnected operation is a mode of operation that enables a client to continue accessing critical data during temporary failures of a shared data repository. The temporary failures may due to networks or data sources breakdown. The core idea behind this work is utilizing tradition performance improving data, such as caching data, to improve availability.
10	Data access in a scalable distributed environment (e.g. a P2P network)	2.618	Data access in a scalable distributed environment (e.g. a P2P network) is analogous to the data access of an ad hoc mobile network. The lookup mechanism used to locate a desire file is analogous to the ad hoc routing operation that locates nearby mobile nodes to forward data jackets.

Table 1. Top 10 Factors of ubiquitous computing drew from CiteSeer

From the WoS dataset, 30 components with Eigenvalue over one collectively explained approximately 86.4% total variances. These components are selected as the representative major themes of ubiquitous computing. Papers with a loading over 0.5 to a component are collected and studied to determine the content of the component. Based on WOS citation data, top 10 components with descriptions and the variances of the components explained are listed in Table 2.

Factor	Component Description	Variance Explained	Description
1	Foundational studies of ubiquitous computing	17.123	Foundational studies of ubiquitous computing provide a generic platform for location and spatial-aware systems. The platform supports a unified spatial-aware infrastructure based on digital models of the physical world. A universal spatial and context-aware infrastructure is essential to overcome the sheer diversity of exploitable contexts and the myriad of sensing technologies.
2	Power aware routing protocol for wireless sensor network	8.329	The availability of small, lightweight low-cost network is crucial to the success of ubiquitous computing. The lightweight network uses energy sparingly to prolong the operational span of the ubiquitous network. The power saving algorithms and protocols are the focus of much ubiquitous computing related research.
3	Medical informatics, application of ubiquitous computing in health care	6.917	The ubiquitous availability of clinical information is major trend in medical informatics research. The application of new information and communication technologies will offer new opportunities and increase the potential of medical informatics methods and tools. The mobility of hospital environment, such as staff, patients, documents and equipments, makes hospitals' ideal applications for pervasive or ubiquitous computing technology.
4	Context-aware workflow language based on Web services	5.105	Research in this factor seems to explore the common feature of Web services and ubiquitous computing. According to W3C, the web services are defined as "a software system designed to support an interoperable machine to machine interaction over a network". The standardization of ubiquitously available services and interoperability between services (factor 1) becomes the natural bond between web services and ubiquitous computing.
5	Context-aware computing	4.878	Papers in factor 5 try to clarify and define the scope and content of context aware computing. Context awareness is the key to dispersing and enmeshing ubiquitous

			computation in our lives. Contextual information is acquired and utilized by devices to provide services that are appropriate to the situational events.
6	Ambient intelligent systems	4.854	Papers in factor 6 extended the context-aware computing to ambient intelligent systems. How "context" can be effectively utilized by a context-aware system, which in turn exhibit ambient intelligent is the focal issue of research in this factor.
7	Open services gateway initiative (OSGi)	4.766	OSGi is technology standard that can coordinate diverse device technologies and enable compound services across different networking technologies. OSGi can be viewed as an initial effort of commercial realisation of the universal spatial and context-aware infrastructure envisioned by the academy.
8	Ubiquitous applications in education	4.350	Articles in factor 8 explore how learning could be augmented by ubiquitous computing devices in an educational setting. The functionalities of traditional classroom equipment and instruments such as whiteboard, notebook PC, PDAs and other learning aids could be augmented by embedding ubiquitous computing power to enhance the learning environment and enriching the learning experiences.
9	Information technology as the competitive advantages of business	3.573	Papers in factor 9 deal with IT and sustained business competitive advantage. IT has been recognized as one of the key competitive advantage for modern businesses. How an organisation builds up its IT capability, streamline its business process, and reconciles its organisational structure are important issues.
10	Tangible and graspable user interfaces	2.903	Factor 10 includes papers on the study of tangible and graspable user interfaces. A tangible user interface lets users using graspable physical objects to emulate the functions of traditional icon-based computer graphical user interfaces. Instead of clicking or dragging a mouse, the tangible user interface tries to carry out the human computer interaction through manipulation of physical objects.

Table 2. Top 10 Factors of ubiquitous computing drew from Web of Science (WOS)

3.3 Pathfinder Network

The Pearson's correlation coefficients between items (papers) are calculated and used as the basis for PFNET scaling. The value of Pearson correlation coefficient falls between the range -1 and 1. Highly correlated items are placed closely together spatially. The nodes located close to the centre of a PFNET graph represents papers contributed to a fundamental concept, which are frequently referred by other peripheral literature that are positioned in outer branches. The distance between items is inversely propositional to the correlation coefficient, which maps less correlated items apart and highly correlated items spatially adjacent.
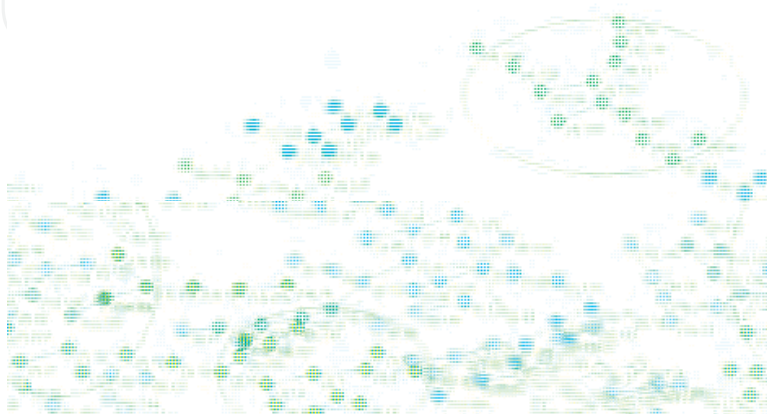
Fig. 2. PFNET Scaling of ubiquitous computing drew from CiteSeer.

Figure 2 represent PFNET scaling of ubiquitous computing from CiteSeer. Articles under the same factor are painted with the same colour. The number in the parenthesis is the factor number which an article belongs to. Cyan nodes with (0) represent articles that are not assigned to any factor. The top ranked components cluster numbered 6, 7, and 12 locate closely to the centre of the PFNET graph (surrounded by a big circle in the centre of the graph), which suggests papers in these components play fundamental roles in ubiquitous computing. A foundational but low-ranked factor may be interpreted as an underdeveloped but important theme in the research field. Component 4 (top left circle, node colour in blue), although ranked high in the amount of variance explained, plays peripheral roles in ubiquitous computing related research. A high-ranked peripheral component is generally an important study, but plays only a supplement role in ubiquitous computing study. Component 3 (lower right circle, node colour in red) plays an interesting role, which indicates that location and context aware computing related researches are important to ubiquitous computing and are important topics in general.

Figure 3 represent PFNET scaling of ubiquitous computing from Web of Science (WoS). Articles under the same factor are painted with the same colour. The number in the parenthesis is the factor number which an article belongs to. Top ranked component cluster number 1, 5, and 6 locate closely to the centre of the PFNET graph (surrounded by a big circle in the centre of the graph), which suggests papers in these components play foundational roles in ubiquitous computing research. Component cluster number 2 (lower-right circle, node colour in green) and 4 (upper right circle, node colour in blue), although ranked high in the amount of variance explained, they play peripheral roles in ubiquitous computing related research. Component cluster number 3 (node colour in red) plays an

interesting role, which indicates that medical informatics research is important to ubiquitous computing as well as an important topic in general.

Fig. 3. PFNET Scaling of ubiquitous computing drew from Web of Science (WoS).

4. Discussion

Abowd and Munatt (Abowd and Munatt 2000) investigate the main research focuses in ubiquitous computing publications in 2000, which include natural interface, context-aware applications and automated capture and access. However, they mainly based on the bounded expertise of the author(s) and a rather limited set of references. We propose a visualising knowledge structure method in analyzing large collections of literatures, which reveals the major research themes and their inter-relationships in ubiquitous computing. We utilize the intellectual structure construction and knowledge domain visualisation techniques developed by the information scientists to ease the task of understanding the main research themes in ubiquitous computing.

Based on the citation papers derived from factor analysis and PFNET in ISI Web of Science (WoS) in 2008, foundational ubiquitous computing studies, context-aware computing, and ambient intelligent systems provide fundamental and important knowledge base to ubiquitous computing studies. Power aware routing protocol and context-aware workflow language are relevant and important studies in general, but only play a supporting or supplemental role in ubiquitous computing research.

In contrast, based on the citation data drew from CiteSeer in 2008, the study of application design for mobile computing, TCP over mobile internetworks and network support for real-time applications provide a fundamental and important technical knowledge base to ubiquitous computing studies. Broadcast based data management for asymmetric communication environments and interacting with computer augmented artefacts and environment are relevant and important studies in general, but only play a supporting or supplemental role in ubiquitous computing studies.

The difference between main themes drew from CiteSeer and WoS CiteSeer is due to that CiteSeer citation index is primarily a computer, information science and engineering citation database, whereas WoS is a comprehensive index. The intellectual structure derived from a predominantly science and engineering oriented index is biased toward the technical aspect of ubiquitous computing. In contrast, WoS is a comprehensive citation database. WoS reveals the application and business themes as well as the technical one.

5. Conclusion

Providing scientists with knowledge visualization tools to reveal the scientific paradigm and movements of such a paradigm is a challenge task. We have introduced the method of visualizing knowledge structures with emphasis on the role of citation-based methods. Factor analysis and Pathfinder Network are used to discover new and significant developments of intellectual structure in the ubiquitous computing research field. Literature published in the online citation databases CiteSeer and Web of Science (WoS) in 2008 were explored to drive the research themes.

We tried to provide a broader view of ubiquitous computing study by applying intellectual structure methods developed by information scientists. The main themes can be uncovered with respect to fundamental and important knowledge as well as supporting or supplemental knowledge in ubiquitous computing domain. The results obtained show that the study of application design for mobile computing, TCP over mobile internetworks, network support for real-time applications, foundational ubiquitous computing studies, context-aware computing, and ambient intelligent systems are fundamental topics in ubiquitous computing. Broadcast based data management for asymmetric communication environments, interacting with computer-augmented artefacts and environment, Power aware routing protocol and context-aware workflow language are relevant and important studies in general, but only play a supporting or supplemental role in ubiquitous computing research.

The benefit of the results obtained could be for someone new to a specific domain in research study. The proposed method may be re-used in other disciplines and share across different research domains. One of the future directions is to apply this proposed method to leverage the research theme networks, which is intellectually interrelated the relationships among publications, citations, research projects, and even patents. We also plan to explore further the interdisciplinary researches in future studies.

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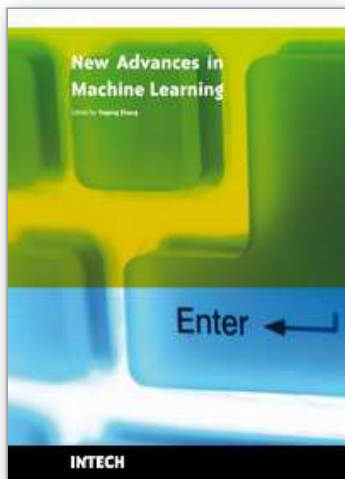
New Advances in Machine Learning

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The purpose of this book is to provide an up-to-date and systematical introduction to the principles and algorithms of machine learning. The definition of learning is broad enough to include most tasks that we commonly call "learning" tasks, as we use the word in daily life. It is also broad enough to encompass computers that improve from experience in quite straightforward ways. The book will be of interest to industrial engineers and scientists as well as academics who wish to pursue machine learning. The book is intended for both graduate and postgraduate students in fields such as computer science, cybernetics, system sciences, engineering, statistics, and social sciences, and as a reference for software professionals and practitioners. The wide scope of the book provides a good introduction to many approaches of machine learning, and it is also the source of useful bibliographical information.

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